COSTS IN ELECTRIC UTILITIES IN THE U.S.: A COMPARISON OF PUBLICLY-OWNED AND PRIVATELY-OWNED UTILITIES IN DIFFERENT MARKET STRUCTURES

By

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This dissertation is dedicated to my parents, Hie Seok and Chong Hyun Koh--my strongest supporters and constant sources of wisdom, virtue and strength, who always have inspired me to scale greater heights.

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This dissertation focuses the effects of ownership and market structure on cost in electric utilities in the U.S. and consists of three parts.

The first part is a brief survey of the literature on the relative efficiency of the different types of ownership and on the relative importance of a competitive environment in attaining a successful privatization program.

In the second part, we construct a theoretical and empirical model which can consider the relative efficiency of publicly-owned and privately-owned utilities allowing simultaneously for the impacts of ownership type, market structure and regulation. We employ the concept of shadow price rather than actual price to reflect the effect of government's regulation.

The method of data construction and empirical results are presented in the third part. The estimation results indicate that privately-owned utilities are more cost efficient than publicly-owned utilities at very large output levels and are less efficient at very small output levels. Contrary to our expectations, the estimates of parameters reflecting different market structure are insignificant. We also produced estimates of economies of scale, demand, and elasticity of substitution.

CHAPTER 1
INTRODUCTION

Introduction

Until World War I, most governments typically exercised only a narrow range of economic activities and imposed essentially no taxes other than the tariff. Most governments assumed only a few responsibilities.

With the development of industries and the complexity of societies, government participation in economic and business activities has gradually increased. Government regulation of some private operations has also increased. There has been more emphasis on macroeconomic planning and management, and there was a great expansion of the public sector in the 1960s and early 1970s. There was no objection to this expansion, since it seemed to play an important role not only in economic growth but also in social and political stability. This trend has been reflected in popular dictionaries and specialized reference work.[1]

However, from the mid-1970s, the economic situation was dramatically changed and, thereby, both the efficiency and effectiveness of more government spending, ownership, and intervention have been seriously questioned. This has sparked new debate about the merits of public versus private ownership. Subsequently, the word "privatize" was recognized, and privatization emerged as the focal point of the debate. Hemming and Mansoor (1988) noted that the word "privatization" appeared for the first time in a reference book in the 1983 edition of the Webster's Ninth New Collegiate Dictionary and that its earliest recorded use is given as being in 1948.[2]

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[1] For example, before 1983, Webster's New Collegiate Dictionary contained an entry for "nationalization" but not for "privatization" (Hanke, 1987).

Although the U.S. economy still remains highly regulated, and the methods and results of regulatory polices are still controversial, the current government regulatory policies of economic activities have moved to deregulation. On the other hand, industries that have been subject to government regulation in the U.S. have usually been controlled or owned by government in other nations. Just like a deregulation movement in the U.S. to reduce the range of government intervention, privatization movements have emerged across countries to transfer publicly-owned enterprises to private sectors. In some cases privatization replaces public ownership with economic regulations; in other cases, it produces an unregulated market.

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[2] However, they also noted that Hanke (Washington Post, January 13, 1986) claimed responsibility for popularizing the word "privatization" while serving on the U.S. President's Council of Economic Advisers in 1981 and 1982.

The rest of this chapter examines some theoretical arguments that suggest there may be differences in the cost efficiency between publicly-owned and privately-owned firms, and reviews some empirical studies of this. Before going further into the subject of privatization, it is desirable to examine the previous theoretical arguments and empirical studies which have considered the relative performance of publicly-owned and privately-owned enterprises. Then, chapter 2 considers the joint roles of ownership and market structure, since market structure has been regarded as an important factor for a successful privatization program. Chapter 3 constructs an empirical model which can reflect not only different ownership and regulatory constraints but also market structures, and the data set used in empirical analysis is described in chapter 4. In chapter 5, the empirical results are discussed. Chapter 6 contains concluding comments.

Theoretical Studies on Different Ownership Type

In comparing the relative efficiency between public ownership and private ownership, property rights theory has been often employed. As developed by economists such as Alchian (1965) and Demsetz (1967), property rights theory examines how the different individual incentives created by the system of property rights affect organizational behavior and company performance. Property rights, in this view, specify the social and economic relations that people must observe in their use of scarce resources, including the benefits and the harms which allow owners and others to accompany. A right of ownership comprises several rights: the rights to use an asset, to change it in form, and to transfer all or some of these rights. Insofar as the government restricts these rights, they become "attenuated." Therefore, the key issues of property rights theory are, first, to whom are property rights assigned, and, second, how are they attenuated?

Alchian (1965) noted that property rights in particular resources may be partitioned, so that private property rights may be owned by different individuals, and each of these private property rights may be transferable. He also explained two implications of the transferability of private property rights. First, individuals have more responsibility for the rewards and costs of an activity. Second, transferability creates specialization in knowledge and risk bearing more advantageous .

Demsetz (1967) noted that property rights develop to internalize externalities when the gains from internalization become larger than the costs of internalization. Therefore, the main function of property rights is that of providing incentives to achieve a greater internalization of externalities. Arguing the close relationship between property rights and externalities, he also noted that private ownership internalizes many of the external costs which, under communal ownership, would not be efficiently internalized. That is, since private ownership offers more concentration of benefits and costs, and reduces the cost of negotiating over the remaining externalities, monitoring will be more effective in a private setting.

Accepting the implications of property rights theory, many studies on ownership have cited Alchian's analysis as a means to show privately-owned enterprises to be more efficient than publicly-owned enterprises.

Examining the Australian airline industry--which is comprised of one publicly-owned and one privately-owned enterprise--Davies (1971, 1977) argued that as a result of the transferability of private ownership, ceteris paribus, the privately-owned enterprise is economically more efficient than the publicly-owned enterprise.[3] De Alessi (1980) also noted the nontransferability of publicly-owned firm, and produced evidence supporting the hypothesis that property rights matter.

In short, the studies of property rights theory on the firm indicate that property rights are more attenuated in the publicly-owned firm than in the privately-owned firm. Consequently, the attenuated property rights will lead to lower firm wealth and greater consumption of nonpecuniary goods by the owners, and, on the whole, result in reduced managerial efficiency.

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[3] Davies (1971) also noted that the private firm concerned in his study does not operate in competitive environment, and its position is much the same as privately-owned electric, gas, and water utilities in the U.S.

However, doubting the validity of property rights theory, Frech (1980) noted that the argument in which the attenuated property rights reduces the price of nonpecuniary benefits to the decision maker reflects only a substitution effect. He noted that there is also an income effect; that is, the attenuation reduces effective income to the decision maker, so that it will encourage the reduction of nonpecuniary benefits. Thus, the comparative static result is ambiguous.

Chalk (1987) argued that whether the attenuated property rights actually result in reduced managerial efficiency depends on whether or not that firm is in a competitive environment. That is, in the absence of barriers to entry, the publicly-owned firm must be as efficient as the privately-owned firm to survive in a competitive environment.

The property rights theory has been also challenged by Starr (1989), who argued that property rights theory does not consider any fundamental changes in the modern corporation, which separated ownership and management. In this case, the shareholders in large corporation--that is, owners--can not closely control management in the same way that the owner of the classical firm could.

Although there exist some counterarguments like the above on property rights theory, theoretical studies based on property rights theory have generally argued that, on the grounds of incentive structures, privately-owned firms are more efficient than publicly-owned ones. That is, if other things are equal, the firm's performance is more efficient in private ownership, where ownership is more concentrated. This logic implies that monitoring by citizens of government will be more effective in small cities, where the individual is more likely to have an impact and is less likely to free ride on the monitoring of others.

Empirical Studies on Relative Cost Efficiency of Different Ownership Type

As stated before, most theoretical studies which have considered the effects of public ownership or regulation on the cost efficiency of firms concluded that, ceteris paribus, privately-owned firms are more efficient than publicly-owned, and unregulated firms are more efficient than regulated.

However, several empirical studies on the relative efficiency of publicly-owned and privately-owned electric utilities have shown results inconsistent with those theoretical conclusions. Table 1-1 summarizes the different results of previous empirical studies on the relative cost efficiency of publicly-owned and privately-owned electric utilities. The eleven studies in the Table 1-1 were based on various measures of cost and various specification of cost function. Although these studies utilized different models and dependent variables, their findings provide an aggregate view of the empirical studies on different ownership types.

Consider some of the empirical studies in Table 1-1. Meyer (1975) estimated a quadratic cost function without considering input price variables. Focusing on the distribution rather than generation of electricity, Neuberg (1977) estimated a Cobb-Douglas cost function without considering the price of capital. Both of them concluded that Publicly-owned electric utilities have lower costs than privately-owned utilities.

Färe, Grosskopf and Logan (1985) employed a nonparametric, linear programming technique, and thereby, were able to avoid the restrictive assumptions of the previous empirical models. They used the same data as Atkinson and Halvorsen and found that on average the publicly-owned utilities are slightly more efficient than the privately-owned (although there are no significant differences in overall cost efficiency between publicly-owned and privately-owned utilities), and that the main source of inefficiency is due to the lack of allocative (price) efficiency.

Illustrating the empirical results verifying the A-J hypothesis[4] of production inefficiency among regulated private

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[4] The A-J hypothesis by Averch and Johnson (1962) asserted that a misallocation of economic resources may result from rate-of-return constraints on prices set by regulatory agencies. That is, since the allowed revenue depends on the rate base--capital, the regulated enterprises have an incentive to increase the level of capital beyond what is necessary for economically efficient production. Most of theoretical studies on the A-J hypothesis concluded that unregulated enterprises are more efficient than regulated enterprises. Although empirical results for the A-J hypothesis have been mixed, most of empirical studies have

Table 1-1
Previous Empirical Results
on the Relative Efficiency
of Publicly-owned and Privately-owned Electric Utilities

Publicly-owned more efficient	Privately-owned more efficient	No significant difference
Meyer (1975)	Moore (1970)	Yunker (1975)
Neuberg (1977)	Peltzman (1971)	Färe, Grosskopf and Logan (1985)
Pescatrice and Trapani (1980)	De Alessi (1974)	Atkinson and Halvorsen (1986)
	Hollas and Stansell (1988)	

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verified the hypothesized cost distortion due to rate-of-return regulation.

monopolies, Pescatrice and Trapani (1980) noted that society might be 'better off' with the unregulated publicly-owned enterprises rather than the regulated privately-owned enterprises producing the same product. They also obtained the empirical result consistent with the above statement--that is, publicly-owned utilities are 33% more cost efficient. But, in their empirical studies, the difference in cost structure could be more directly attributed to the ownership type since technology and factor prices were held constant.

Both Pescatrice and Trapani (1980) and Atkinson and Halvorsen (1986) considered the effects of regulation and estimated a generalized translog cost function simultaneously with the cost share functions. But their studies differ in how they handled the effects of regulation. Pescatrice and Trapani (1980) allowed for effects of regulation--that is, use of shadow input prices rather than market input prices--for the privately-owned utilities only. However, Atkinson and Halvorsen (1986) argued that publicly-owned utilities are also subject to regulation and allowed for the effects of regulation for both publicly-owned and privately-owned utilities. According to them, whereas privately-owned utilities may be explicitly bound by the rate of return constraints, publicly-owned utilities may be implicitly constrained by the requirement that they minimize output prices subject to earning an adequate rate of return to maintain their bond rating.

Contrary to Pescatrice and Trapani's (1980) result, Atkinson and Halvorsen (1986) found that there is no significant difference in allocative efficiency between publicly-owned and privately-owned electric utilities and the two types of enterprises are equally cost inefficient in the U.S.

Hollas and Stansell (1988) also considered the effects of regulation, but did not employ the concept of shadow prices in incorporating the effects of regulation. Employing a Unit-Output-Price (UOP) profit function,[5] which was developed by Lau and Yotopoulos, they estimated the short-run translog profit function by treating capital as a fixed input. They divided ownership type of electric utilities into three categories: privately-owned utilities; cooperative utilities, which are defined as privately-owned but presumably not profit maximizing firms; and publicly-owned utilities. Their results

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[5] By using the price of output as numeraire, Lau and Yotopoulos (1971) defined "Unit-Output-Price" profit, P, as

$$P = \frac{\dot{P}}{p} = F(X_1, \cdots, X_m; Z_1, \cdots, Z_n) - \sum_{i=1}^{m} c_i X_i$$

where X_i and Z_i are the variable inputs and the fixed variables respectively, $\dot{p}$ is profit defined as current revenues less current total variable costs, p is the unit price of output, c_i is the unit price of ith variable input divided by the price of output. Thus UOP profit function, π, is the function of the normalized prices of variable inputs X_i, and the fixed inputs.

$$\pi = \pi(c_1, \cdots, c_m; Z_1, \cdots, Z_n)$$

(The notations in this footnote have nothing to do with those in the text.)

showed that the cooperatives are more price efficient than publicly-owned utilities, but less efficient than privately-owned utilities.

The evidence in the many empirical studies described above on the relative efficiency of publicly-owned and privately-owned electric utilities is mixed. Accordingly, additional research, which remedies several shortcomings of the previous studies, is required.

In our model of the relative cost efficiency of publicly-owned and privately-owned electric utilities, we will follow Atkinson and Halvorsen's (1986) logic allowing for the effects of regulation on both types of ownership and will expand their framework to allow market structure also to affect cost.

CHAPTER 2
THE JOINT ROLES OF OWNERSHIP AND MARKET STRUCTURE

Introduction

The previous chapter focused on ownership type and examined how the structure of ownership affects the firm's performance. However, from the existing empirical literature, it is difficult to conclude which type of ownership provides a better performance in the firm's operation.

The empirical literature on the electric power industry is typical. Many studies on the relative efficiency of publicly-owned and privately-owned enterprises in industries such as water, refuse collection, health-related service (including hospitals), airline, railroad, and bank and financial service industry have been undertaken, and the evidence in these studies is also mixed.

A major problem with the empirical studies on the relative efficiency of publicly-owned and privately-owned enterprises is that they only concern the relationship between ownership type and performance. For example, those studies assumed that enterprises in the relevant industries were natural monopolies or contiguous monopolies. That is, they did not consider the effects of different market structure--for example, competitive environment--in comparing the performance between publicly-owned and privately-owned enterprises.

Therefore, based on the arguments that some competition exists in the electric power industry (Weiss, 1975), and that activity such as the generation of electricity in electric power industry is not a natural monopoly (Moore, 1983), it is important to examine how the effects of different market structures interact with the different ownership types in the electric industry.

Privatization and Market Structure

Privatization and Competition

Regardless of the results of previous empirical studies, the poor performance of publicly-owned enterprises has been often reported, and there have been many efforts to improve their poor performance. But those efforts for the most part have been judged unsuccessful, and attention is now likely to turn to a privatization program.

The main arguments for privatization are that transferring the publicly-owned enterprises to the private sector will expose these enterprises to the discipline of the market, through the incentive system, and lead them to increase efficiency. In other words, since the product market may provide consumers the possibility of transferring their business to other firms, and the capital market can impose the threat of bankruptcy or of takeover, we can expect the privatized enterprises to increase efficiency through the discipline of the product market, or of the capital market, or of both.

However, as Hemming and Mansoor (1988) noted, to study whether privatization can make the publicly-owned enterprises more efficient or whether privatization can provide the incentives for enterprises to increase efficiency, it is necessary to distinguish between (1) the publicly-owned enterprises that are already subject to national or international competition and (2) those that are in monopolistic positions. This is because it is usually accepted that the competitive environment can provide the incentives for enterprises to increase both productive (or internal) and allocative efficiency.[6]

Generally, in the first case, there are no strong grounds for keeping public ownership of enterprises in the competitive environment which increases allocative efficiency. Furthermore, arguing that privatization by itself increases productive efficiency, Forsyth (1984) noted that whatever the market structure, in the absence of regulation, a privately-owned enterprise which is allowed to maximize profit has a direct incentive to minimize cost for whatever output it chooses.

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[6] Productive (or internal) efficiency means the production of a given output at minimum total cost, given input prices. Allocative efficiency means that an output in distributed efficiently (i.e. to those who value it most), and that the level of output which is most valued is chosen (Forsyth 1984). That is, setting price equal to unit cost gives perfect incentives for allocative efficiency but no incentive for cost reduction. Setting price equal to a given constant gives perfect incentives for productive efficiency but poor allocative efficiency (Vickers and Yarrow, 1988).

In the second case, we may expect a great increase in efficiency from privatization of the publicly-owned monopolies. But, in this case, there is the common belief that in so far as the privatized enterprises can retain their monopolistic position--for example, either because they are natural monopolies or because statutory protection continue--efficiency increases will be due to productive efficiency, not allocative efficiency. Forsyth (1984) also noted that privatization by itself gives no incentive for allocative efficiency. That is, when the privately-owned enterprise is not operating in a competitive environment, but retaining a monopolistic position, that enterprise has a strong incentive to depart from allocative efficiency.

In summary, it can be said that privatization tends to increase productive efficiency; competition tends to increase allocative efficiency. Only a competitive, privately-owned enterprise has incentives to increase both productive and allocative efficiency.

Limitations to Competition

Even if such competition is the primary means for increasing allocative efficiency, there are several limitations to the promotion of competition in the nationalized industries. First, the existence of many publicly-owned enterprises is based on market failure, and some of them are natural monopolies. Second, when the publicly-owned enterprise is operated in a contestable market, competition may not be appropriate. Third, there are some statutory monopolies--entry has been subjected to legal restrictions. These limitations are considered in the following sections.

Natural monopoly

Public ownership is one of the main solutions to market failure in the industries where competition is impossible or undesirable, or where major externalities exist. Especially, in an industry dominated by natural monopolies such as electricity, gas, water, railways, refuse collection and telecommunications, competition has been regarded to be undesirable, thus, restricted. In other words, because of their integrated networks nature, natural monopoly in those industries has seemed to make economic and business sense.

However, Weiss (1975) noted that electricity generating plants can be in competition if the plants are under separate ownership and had equal access to transmission and distribution, and argued that the generation of electricity should be vertically disintegrated from its transmission and distribution. Similarly, Moore (1983) argued that activities such as the generation of electricity, the production of gas, bus transport, the treatment and disposal of sewerage, and telecommunication (other than local district services) are in no sense natural monopolies. Kay and Thompson (1986) also noted that in the industries which involve distribution networks, the cost of providing two competing networks would not be less than twice the cost of provision through a single system, but this is less true in the current telecommunication industry where the technology is rapidly widening supply possibilities. Bishop and Kay (1989) noted that an appropriate strategy in natural monopoly sectors may be the separation of the ownership of activities where competition is possible from the genuine natural monopoly activities. For example, according to them, while the above principle has not, in general, been followed in the U.K. privatization policy, the above principle was the basis of the reconstruction of the U.S. telecommunication industry.

There are other proposals to stimulate competition in natural monopoly sectors through the diverse privatization program. Hemming and Mansoor (1988) suggested that many associated activities of natural monopoly--maintenance, refuse collection--can be contracted out to the private sector through competitive bidding.

Contestability

Privatization of the publicly-owned enterprises in the competitive environment raises few problems in industrial policy. But, if the incumbent firm--regardless of publicly-owned or privatized firm--in the competitive environment has a dominant market share, the mechanism of competition cannot reflect its superiority. Therefore, it is only the entry and growth of new rivals that can provide competitive disciplines against the incumbent firm.

However, it is commonly argued that full competition through free entry is not essential to achieve the social welfare;[7] instead, the threat of competition--that is, potential competition--may be sufficient. A lot of arguments for potential competition have been based on the theory of contestable markets by Baumol, Panzar, and Willig (1982). According to them, a monopolistic firm is said to operate in a contestable market when its behavior approximates that of a competitive firm. In this case, if a monopolistic firm does not behave as if it were subject to competition, other firms will attempt to cream-skim the monopoly profits. That is, the entry threat by the potential entrants is sufficient for a monopolistic firm to behave efficiently. Of course, the above condition can exist only in the absence of barriers to exit--in other words, sunk cost should be zero or low.

However, Hemming and Mansoor (1988) noted that in the case of the traditional publicly-owned monopolies--that is, enterprises to be considered as the target of privatization program--which need large amounts of investments that cannot be recovered on exit, contestability is unlikely to be relevant.

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[7] For more details about the trade off between scale economies and social efficiency, see von Weizsäcker (1980), Perry (1984), and Mankiw and Whinston (1986).

Vickers and Yarrow (1988) noted that the incumbent firm with dominant market power may be able to make even potential competitors impotent by strategic entry deterrence and predatory behavior. They also pointed out that this is a central question for privatization in the U.K., because major enterprises such as British Telecom and British Gas have privatized with positions of great dominance. Accordingly, emphasizing that direct regulation is necessary to protect the potential entrants from the dominant firm's anticompetitive behavior, they argued that the contestability theory does not justify privatization of major industries such as telecommunication, energy and water, etc.

Statutory Monopoly

Some nationalized industries have been created by statute rather than because they are natural monopolies. Kay and Thompson (1986) noted that in the U.K., airlines, buses and the provision of subscribers' equipment in telecommunication are examples of statutory monopoly. In such cases, it might be expected that competition would be achieved by the simple repeal of the restrictive statutes--that is, liberalization.

However, even if liberalization is implemented, the incumbent firm may retain significant market power in the liberalized industry. In other words, the initial technical and financial advantages which the incumbent firm brings to the liberalized industry are likely to deter new entrants. For example, experiences in the U.K. have shown that the mere removal of legal obstacles is not sufficient to ensure real competition.

Davis (1984) illustrated this issue analyzing the liberalization of the express coach industry in the U.K. According to him, since National Express, which is the publicly-owned enterprise, made use of the continued predominant position and the exclusive access to city center coaching terminals in the liberalized industry, liberalization in the express coach industry did not reduce National Express' dominant market share.[8]

Bishop and Kay (1989) suggested that, to solve the problem of a continued dominant position of the incumbent firm in the liberalized industry, government can respond with a program of restructuring the incumbent firm into its constituent competitive parts--for example, splitting the business into regional operating companies. According to them, three advantages can be expected by restructuring. First, by reducing the size of privatized enterprise, its acquisition or reorganization will be facilitated if performance is undesirable. Second, it will facilitate the generation of comparative information on split companies--for example, if each local gas distribution network is separately owned, shareholders can compare and assess their firm's performance with a whole range of similar firms. Third, the regulatory authority can respond with the appropriate regulations through such comparative assessments.

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[8] Davis (1984) also noted that liberalization of the express coach industry resulted in price reductions and service innovation, and concluded therefore that the consequences of liberalizing express coach industry have been broadly beneficial.

In summary, the appropriately designed restructuring of publicly-owned enterprises--for example, integrated nationalized monopolies--which have been protected by statutory restrictions will have a potentially important role in the development of both product market competition and effective capital market constraints.

Privatization and Liberalization

As stated before, transferring the publicly-owned enterprises into the private sector may be expected to increase productive efficiency, but not allocative efficiency, because allocative efficiency is a function of market structure rather than ownership. That is, increase in allocative efficiency can be expected only when privatization policy is accompanied by liberalization policies removing market restrictions. Therefore, given the importance of establishing competitive environment through liberalization policies, it is necessary to note the relationship between privatization and liberalization.

First of all, it is necessary to keep in mind the fact that privatization program by itself does not construct competitive environment. That is, public ownership by itself does not imply nationalized monopoly, and private ownership by itself does not entail competition. For example, Foreman-Peck and Manning (1986) pointed out that because statutory monopolies have often gone hand in hand with public ownership in Western Europe, liberalization may be easily confused with privatization. But they argued that since abolishing monopoly and extending consumer rights do not necessarily require the transferring the publicly-owned enterprises into private sector, and vice versa, liberalization has to be distinguished from privatization.[9]

Second, there are arguments that liberalization can not proceed successfully without privatization. According to Hemming and Mansoor (1988), these arguments are usually due to the possibility of predation by the dominant publicly-owned enterprise in the liberalized industry. However, although the possibility of predation can obviously exist in the liberalized public sector, the substantial predatory practices are more often likely to occur in the private sector. Therefore, the possibility of predation does not imply that privatization is necessary for liberalization, but it just implies that liberalization by itself cannot encourage competition successfully without the appropriate regulation to deter anticompetitive practices.

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[9] Arguing that liberalization and privatization are logically independent policies, Foreman-Peck and Manning (1986) examined the implementation and impact of only liberalization in the telecommunications manufacturing industry.

Third, there are another important thing to note in the relationship between privatization and liberalization. Although both privatization and liberalization are desirable to improve competition, there are some cases which government does not pursue both of them simultaneously. For example, since one of the objectives of privatization may be to generate budgetary revenue, and the market value of an enterprise to privatize is determined by its current and future profitability, government which may have motive to generate more revenue, therefore, may restrict competition to boost the market value of an enterprise to privatize. For example, Kay and Silberston (1984) argued that the above case was happened in the privatization of British Telecom in the U.K. Therefore, as Hemming and Mansoor (1988) argued, as a rule, when privatization and liberalization come into conflict, the latter should be preferred since privatization can more readily follow liberalization than vice versa.

Remark

So far, we have examined the importance of market structure in privatization programs. According to the above arguments, it can be said that the increased efficiency achieved through a privatization program is due to the competitive force in those industries rather than the change in ownership.

Unfortunately, although a large number of studies on the relative performance of publicly-owned and privately-owned enterprises have been conducted, most of them have focused exclusively on the ownership variable (in the recent literatures, regulation is considered), but have failed to take into account the effects of different market structures.[10]

Keeping in mind the above arguments, if we want to compare the relative efficiency between publicly-owned and privately-owned, we have to consider in which market structures the selected enterprises are operating. In other words, as the studies on different ownership in electric power industry which ignore the effects of regulation are faulty, the studies which neglect the effects of different market structures might also be incomplete.

Now, we will incorporate the variable reflecting different market structures into our model to consider the joint roles of ownership and market structure. By doing this, not only can we compare the relative efficiency of publicly-owned and privately-owned electric utilities, but also can we test whether market structure really affects the impact of privatization.

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[10] Vickers and Yarrow (1988) indicated two reasons for this failure. First, there are data problems--that is, the limited number of observations make it difficult to conduct multifactor analyses. Second, there are theoretical failures--that is, even where sufficient data are available, statistical tests have rarely been sophisticated enough to consider the interacting effects of ownership, regulation and market structure on the firm's performance.

CHAPTER 3
THE MODEL

Introduction

As we mentioned in chapter 1, the property rights theory developed by Alchian (1965) and Demsetz (1967) has provided the dominant explanation for the effect of ownership type on firm behavior--that is, on the cost efficiency of the firm. Most of these theoretical studies suggested that privately-owned enterprises are more efficient than publicly-owned enterprises. However, previous empirical studies on the relative efficiency of publicly-owned versus privately-owned enterprises have shown results inconsistent with those theoretical conclusions.

Atkinson and Halvorsen (1986) argued that the inconsistences may result from two factors. One is that the previous empirical studies may have had some problems on econometric grounds. The other is that the previous empirical studies were testing a hypothesis on the joint effects of ownership and regulation, whereas the theoretical studies have generally considered only their partial effects and have failed to consider the joint effects.

This chapter examines the relative cost efficiency of publicly-owned and privately-owned electric utilities taking into account the effects of ownership, regulation and market structure. The models employ the concept that the behavior of a utility maximizing regulated firm is in effect equivalent to cost minimization subject to shadow input prices which reflect the effects of regulation, rather than market input prices. Therefore, following Atkinson and Halvorsen (1986), the model is based on a generalized cost function that retains the advantages of the neoclassical cost function but does not require that cost minimization subject to market prices be imposed as a maintained hypothesis. In this context, the actual cost function and the actual cost share equations are estimated simultaneously.

Theoretical Model

Assume that managerial utility is a function both of profit and the quantities of the inputs.

(3-1) $U = U(\pi, X)$

where $U(\cdot)$ is a twice continuously differentiable concave utility function, π is profit, and X is a vector of inputs. Since the firm's profit may be positively related with pecuniary benefits (e.g. dividends for stockholders) and nonpecuniary benefits (e.g. job security or prestige for managers), we assume that $\frac{\partial U}{\partial \pi} > 0$. On the other hand, since inputs may entail pecuniary benefits, nonpecuniary benefits, or nonpecuniary costs, we assume that $\frac{\partial U}{\partial X_i}$ may be positive, negative, or zero depending on the specific inputs.

For a firm facing a downward-sloping demand curve, profit equals

$$(3\text{-}2) \qquad \pi = R(X) - \sum_{i=1}^{n} p_i X_i$$

where R(·) is a twice continuously differentiable concave revenue function, and p_i is the market price of input i.

Considering the effects of regulation, we assume that both publicly-owned and privately-owned enterprises may be subject to profit constraints, $\pi \leq G(X^G)$. Thus,

$$(3\text{-}3) \qquad R(X) - \sum_{i}^{n} p_i X_i \leq G(X^G)$$

where G(·) is the regulatory constraints function imposed by the firm's regulatory environment. And, X^G is the vector of input variables reflecting various aspects of regulation.

The Lagrangian for a company's utility maximization under regulation is

$$(3\text{-}4) \qquad \begin{aligned} \mathcal{L} = U(\pi, X) &- \lambda \left[\pi - R(X) + \sum_{i=1}^{n} p_i X_i\right] \\ &- \sum_{k} \mu_k \left[R(X) - \sum_{i=1}^{n} p_i X_i - G^k(X^{G^k})\right] \end{aligned}$$

where μ_k is the Lagrange multiplier for the regulatory constraint involving $G^k(X^{G^k})$.[11]

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[11] The notation $G^k(X^{G^k})$ is used to indicate that the vector of inputs entering each constraint will generally

The first order condition for a company's utility maximization for input i is

$$(3\text{-}5) \qquad \frac{\partial \mathcal{L}}{\partial \pi} = \frac{\partial U}{\partial \pi} - \lambda = 0$$

$$(3\text{-}6) \qquad \begin{aligned} \frac{\partial \mathcal{L}}{\partial X_i} &= \frac{\partial U}{\partial X_i} - \lambda \left[-\frac{\partial R}{\partial X_i} + p_i \right] \\ &\quad - \sum_k \mu_k \left[\frac{\partial R}{\partial X_i} - p_i - \frac{\partial G^k}{\partial X_i} \right] = 0 \end{aligned}$$

Substituting eq.(3-5) into eq.(3-6),

$$(3\text{-}7) \qquad \frac{\partial R}{\partial X_i} = p_i - \frac{\dfrac{\partial U}{\partial X_i} + \sum_k \mu_k \dfrac{\partial G^k}{\partial X_i}}{\dfrac{\partial U}{\partial \pi} - \sum_k \mu_k}$$

The left-hand side of eq.(3-7) is the marginal revenue product of input i. The right-hand side of eq.(3-7) differs from the market price for input i, p_i, because it is reflecting the effect of government's regulation as well as the company's utility maximizing behavior. Thus we will call the right-hand side of eq.(3-7) the shadow price for input i, p_i^*.

We divide equation eq.(3-7) by the equivalent equation for input j,

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differ (Atkinson and Halvorsen, 1986).

$$(3\text{-}8) \qquad \frac{\dfrac{\partial R}{\partial X_i}}{\dfrac{\partial R}{\partial X_j}} = \frac{p_i - \dfrac{\dfrac{\partial U}{\partial X_i} + \sum_k \mu_k \dfrac{\partial G^k}{\partial X_i}}{\dfrac{\partial U}{\partial \pi} - \sum_k \mu_k}}{p_j - \dfrac{\dfrac{\partial U}{\partial X_j} + \sum_k \mu_k \dfrac{\partial G^k}{\partial X_j}}{\dfrac{\partial U}{\partial \pi} - \sum_k \mu_k}} = \frac{p_i^*}{p_j^*}$$

The left-hand side of eq.(3-8) is equal to the marginal rate of technical substitution between input i and input j, $MRTS_{ij}$. Because,

$$(3\text{-}9) \qquad \frac{\dfrac{\partial R}{\partial X_i}}{\dfrac{\partial R}{\partial X_j}} = \frac{\dfrac{\partial R}{\partial Q} \cdot \dfrac{\partial Q}{\partial X_i}}{\dfrac{\partial R}{\partial Q} \cdot \dfrac{\partial Q}{\partial X_j}} = \frac{\dfrac{\partial Q}{\partial X_i}}{\dfrac{\partial Q}{\partial X_j}}$$

where Q is the quantity of output. Before we continue, we need to note that, for the unregulated profit maximizing companies, cost minimization subject to the market prices implies that marginal rates of technical substitution are equal to the ratio of market prices for the inputs. However, the right-hand side of eq.(3-8) is not the ratio of market prices for inputs, but the ratio of shadow prices for inputs.

On the other hand, if there were no binding regulatory constraints ($\mu_k = 0$) and no managerial distortions ($\frac{\partial U}{\partial X_i} = 0$), eq.(3-8) would be,

$$(3\text{-}10) \qquad \frac{\dfrac{\partial R}{\partial X_i}}{\dfrac{\partial R}{\partial X_j}} = \frac{p_i}{p_j} = \frac{p_i^*}{p_j^*}$$

That is, if there were no binding regulatory constraints, the shadow prices would be same as the market prices, and we do not need the concept of shadow prices any more.

Considering the effects of regulatory constraints, several studies have explicitly incorporated the rate of return constraint in their empirical models. That is, those studies have assumed that the rate of return constraint is only relevant for regulatory constraints. But, although this approach is meaningful in incorporating explicitly the assumed effects of regulation, it is also subject to several criticisms. Atkinson and Halvorsen (1984) pointed out these shortcomings as follows. First, it is notable that the rate of return constraint is only one aspect of the regulatory environments. For example, electric utility companies are subject not only to rate of return constraints but also to other important regulations including fuel adjustment clauses[12] and environmental regulations.[13] Second, the rate of return regulated cost function usually does not satisfy the necessary condition of quasi-concavity in prices, and thus, the use of Shepherd's Lemma may not be valid in general.

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[12] Atkinson and Halvorsen (1981) tested simultaneously for the A-J hypothesis and fuel adjustment clauses. Their results showed input inefficiency between capital and labor by the A-J hypothesis and input inefficiency between labor and fuel by fuel adjustment clauses. But their results also showed that there is no evidence of input inefficiency between capital and fuel because the A-J bias and fuel adjustment clauses bias are offsetting one another.

Therefore, to avoid the drawbacks of models that attempted to incorporate explicitly regulatory constraints, Atkinson and Halvorsen (1986) employed an alternative approach based on the use of simple parametric approximations of the shadow prices in eq.(3-8)--that is, a company's utility maximizing behavior under regulation has to be modelled as cost minimization subject to appropriately defined shadow prices.

For more detailed explanation on the concept of shadow price, it can be said that Lau and Yotopoulos (1971) originally applied the concept of shadow prices in defining the concepts of relative and absolute price efficiency. Their use of the shadow prices is based on the following assumptions. First, the prices of inputs differ across firms, and each firm equates the value of marginal product of each input to its firm-specific opportunity cost. Second, some firms may not maximize profits. In this case, the usual marginal conditions do not hold. Thus, they assumed that firms equate the value of marginal product of each input to a

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[13] Atkinson and Halvorsen (1984) noted that environmental regulations include restrictions on the types of fuel which utility companies use. Thus environmental regulations can result in divergences between the market prices and the shadow prices of fuel even in the absence of other types of regulation.

constant (which may be firm-specific and input-specific) proportion of the respective firm-specific input prices. That is, for firm 1,

$$\text{(3-11)} \qquad \frac{\partial R^1}{\partial X_i^1} = k_i^1 p_i^1 \; , \qquad\qquad k_i^1 \geq 0$$

where k_i^1 indicates divergences from the firm's efficient behavior--that is, the decision rule which describes the firm's profit maximizing behavior with respect to input i. Lau and Yotopoulos also noted that the k's may be interpreted as the first-order coefficients of a Taylor's series expansion of arbitrary decision rules--in this context, a shadow price function. That is, a shadow price function, $f_i(p_i)$, which is from eq.(3-11), has the following properties:

$$f_i(0) = 0 \quad , \quad \frac{\partial f_i(p_i)}{\partial p_i} \geq 0$$

Given these concepts, the relative price efficiency with respect to inputs i and j holds if $k_i^1 = k_j^1$, and the absolute price efficiency with respect to input i holds when $k_i^1 = 1$.

From eq.(3-11), treating the product of k_i and p_i as the effective normalized price of input i, Atkinson and Halvorsen (1984) assumed that the shadow price for input i of firm j is approximated by

$$\text{(3-12)} \qquad p_i^{j*} = k_i^j p_i^j$$

where k_i^j is the factor of proportionality, which is input and firm specific. Therefore, in our study it is assumed that k_i^j can vary across ownership types. Using this shadow price approach, we will derive a generalized cost function that allows for departures from cost minimization subject to the market prices.

Empirical Model

Assuming that firms employ inputs to minimize the total shadow cost, $\Sigma(k_i p_i)X_i$, of the given level of output, the firm's dual total shadow cost function can be defined as

$$C^s = C^s(kp, Q, Z) \quad (3\text{-}13)$$

where kp is a vector of input specific and firm specific shadow prices, Q is the quantity of output, and Z is a vector of variables reflecting various market structures, which can include monopoly, duopoly, and competition. Here, we need some explanation for entering Z, a vector of variables reflecting market structures.

As argued in chapter 2, on theoretical grounds, the relative performance of publicly-owned and privately-owned companies depends on a range of factors which include the respective monitoring systems, regulatory policy, technical efficiency, and the degree of competition in the market. Therefore, empirical studies on the evaluation between publicly-owned and privately-owned enterprises should also consider these various factors. As pointed out by Vickers and Yarrow (1988), although a large number of empirical studies on the effects of different ownership have been conducted, the results of these empirical studies are less informative than might be anticipated. A reason is that many empirical studies have focused almost exclusively on the effects of different types of ownership (in recent work, the effects of regulatory constraints are also considered), but have failed to consider the effects of different market structures.

On the other hand, with the advent of the terminology "privatization", there has been much dispute about privatization. Similar to the arguments in the preceding paragraph, the most notable arguments made in the studies about privatization are that, to be a successful privatization, the privatized utility companies must be disciplined by an appropriate competitive environment. For example, van de Walle (1989) concluded that in the absence of other policy reforms which increase competition in the economy, the impact of privatization on economic efficiency is likely to be modest.

Boardman and Vining (1989) also noted that the previous empirical studies generally concerned either natural monopolies or regulated duopolies and thus could not address whether publicly-owned enterprises will be as efficient as privately-owned enterprises in competitive environments. Thus testing the effects of property rights, they compared three types of ownership--state-owned enterprises (SOEs), mixed enterprises (MEs) and private corporations (PCs)--in competitive environments.[14] They found that mixed enterprises were less efficient than the other types of ownership. However, since their study did not consider market structures other than competitive environments, their study also could not disentangle the efficiency increases or decreases that are due to private ownership from those which resulted from the competitive market structure. Another thing to note is, since the terminology "privatization" is defined as the transfer of ownership of the same enterprise, it is not proper to deduce the results of privatization from their study comparing enterprises regardless of the kinds of industries.

In our study, by entering the vector of variables reflecting various market structures into the total shadow cost function, we might find different results from the previous studies which did not consider market structures. Moreover, by considering monopolistic and competitive environments simultaneously, we can confirm whether competition is really a significant factor in the privatization program as a lot of studies on privatization have argued. For example, if we find that publicly-owned and privately-owned utility companies in competitive environments have better performance than any privately-owned and publicly-owned utility companies in monopolistic environments, then, we have to emphasize the market structure--that is, competitive environments--rather than the transfer of ownership through privatization programs.

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[14] Their dataset consists of the 500 largest manufacturing and mining corporations in the world outside the U.S. as compiled by Fortune magazine in 1983. From their dataset, example of SOEs is British Coal Board, examples of MEs are British Petroleum, Canada Development Corporation and Volkswagen, and examples of PCs are Nissan and Nestlé.

Returning to eq.(3-13), the actual demand functions for the inputs of production can be calculated by partially differentiating the total shadow cost function with respect to the shadow prices for inputs--that is, by applying Shephard's Lemma (1970),

$$\text{(3-14)} \qquad \frac{\partial C^s}{\partial k_i p_i} = X_i$$

And, the firm's total actual cost, C^A, is

$$\text{(3-15)} \qquad C^A = \sum_{i=1}^{n} p_i X_i = \sum_{i=1}^{n} p_i \frac{\partial C^s}{\partial k_i p_i}$$

To derive a parametric expression for the firm's total actual cost, an appropriate functional form for the shadow cost function must be specified.

Before we derive an appropriate functional form for the shadow cost function, let's define the shadow cost share of input i as S_i^S for simplicity.

$$\text{(3-16)} \qquad S_i^S \equiv \frac{k_i p_i X_i}{C^S}$$

From eq.(3-16),

$$(3\text{-}17) \qquad X_i = S_i^s C^s (k_i p_i)^{-1}$$

Substituting eq.(3-17) into eq.(3-15),

$$(3\text{-}18) \qquad C^A = C^s \sum_{i=1}^{n} k_i^{-1} S_i^s$$

Taking natural logarithms of eq.(3-18),

$$(3\text{-}19) \qquad \ln C^A = \ln C^s + \ln \sum_{i=1}^{n} k_i^{-1} S_i^s$$

Now, we will employ the transcendental logarithmic (translog) functional form for an appropriate functional form for the shadow cost function.[15] Lau (1974) argued that almost all of the more "flexible" functional forms used in econometric applications of duality theory claim to be second order approximations.[16] Diewert (1974) showed that the translog cost function is a "flexible" functional form, which could be defined as one which is capable of providing a second order approximation to an arbitrary cost function. Thus he also noted that the translog cost function provides a second order approximation to an arbitrary continuously twice differentiable shadow cost function.

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[15] Christensen, Jorgenson, and Lau (1971, 1973) introduced the transcendental logarithmic function to test the theory of production that do not employ additivity and homogeneity as part of the maintained hypothesis, and to exploit the duality between prices and quantities in the theory of production. They also suggested that the translog function should be employed in the absence of correct a priori information on the specific functional form.

[16] Lau (1974) identified two different definitions of a second order approximation. One is a second order numerical approximation by Christensen et al.'s concept (1973), and the other is a second order differential approximation by Diewert's (1974) concept. From the above two concepts, it is notable that any approximating function G(y) that may be interpreted as a second order Taylor's series approximation around y_0 is both a second order differential approximation and a second order numerical approximation. However, it is not in general true that a second order differential approximation is also a second order numerical approximation. For more details, see Lau (1974).

From eq.(3-13), the translog functional form for the shadow cost function is,

$$\begin{aligned} \ln C^{S} = {} & \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(k_i p_i) + \alpha_Q \ln Q + \alpha_Z Z^{v} \\ & + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln(k_i p_i) \ln(k_j P_j) \\ & + \frac{1}{2} \beta_{QQ} (\ln Q)^2 + \sum_{i=1}^{n} \beta_{iQ} \ln(k_i p_i) \ln Q \\ & + \sum_{i=1}^{n} \beta_{iZ} \ln(k_i p_i) Z^{v} + \beta_{QZ} (\ln Q) Z^{v} \end{aligned} \tag{3-20}$$

where $\beta_{ij} = \beta_{ji}$, $i \neq j$, which implies the restriction of symmetry. And, Z^{v} is a dummy variable reflecting two market structures--monopolistic and competitive environments. To distinguish these market structures, we will define $v = M$ for monopolistic environment, $v = C$ for competitive environment. Thus, $Z^{M} = 1$, and $Z^{C} = 0$.

In order to correspond to a well-behaved production function, the total shadow cost function, eq.(3-20), should be homogeneous of degree one in shadow prices; that is, if we hold fixed the level of output and the market variable, total shadow cost must increase (or decrease) proportionally whenever all shadow prices increase (or decrease) proportionally. This is done when the following restrictions on the parameters are satisfied,

$$\sum_{i=1}^{n} \alpha_i = 1,$$

$$(3\text{-}21) \qquad \sum_{i=1}^{n} \beta_{iQ} = 0, \qquad \sum_{i=1}^{n} \beta_{iZ} = 0,$$

$$\sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \beta_{ij} = \sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} = 0$$

Next, we need the parametric expressions for the shadow cost shares of input i, S_i^S , and which will be derived by logarithmic differentiation of eq.(3-20).

$$(3\text{-}22) \qquad \frac{\partial \ln C^S}{\partial \ln(k_i p_i)} = \frac{1}{C^S}\frac{\partial C^S}{\partial (k_i p_i)} k_i p_i = \frac{k_i p_i X_i}{C^S}$$

Comparing with eq.(3-16), eq.(3-22) is equal to the shadow cost shares of input i, S_i^S . Also,

$$(3\text{-}23) \qquad \frac{\partial \ln C^S}{\partial \ln(k_i p_i)} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^V$$

Thus, the shadow cost shares are,

$$(3\text{-}24) \qquad S_i^S = \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^V$$

Next, the corresponding total actual cost function can be derived by substituting eq.(3-20) and eq.(3-24) into eq.(3-19),

$$
\begin{aligned}
\ln C^A = {} & \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(k_i p_i) + \alpha_Q \ln Q + \alpha_Z Z^V \\
& + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln(k_i p_i) \ln(k_j P_j) \\
(3\text{-}25) \qquad & + \frac{1}{2}\beta_{QQ} (\ln Q)^2 + \sum_{i=1}^{n} \beta_{iQ} \ln(k_i p_i) \ln Q \\
& + \sum_{i=1}^{n} \beta_{iZ} \ln(k_i p_i) Z^V + \beta_{QZ} (\ln Q) Z^V \\
& + \ln\{\sum_{i=1}^{n} k_i^{-1} [\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) \\
& + \beta_{iQ} \ln Q + \beta_{iZ} Z^V]\}
\end{aligned}
$$

Atkinson and Halvorsen (1984) noted that additional degrees of freedom can be obtained by estimating the firm's actual cost share equations together with its total actual cost function.

Let's define the actual cost share of input i as S_i^A

$$
(3\text{-}26) \qquad S_i^A \equiv \frac{p_i X_i}{C^A}
$$

Substituting eq.(3-17) and eq.(3-18) into eq.(3-26),

$$
(3\text{-}27) \qquad S_i^A = \frac{p_i S_i^S C^S (k_i p_i)^{-1}}{C^S \sum_{i=1}^{n} k_i^{-1} S_i^S} = \frac{S_i^S k_i^{-1}}{\sum_{i=1}^{n} S_i^S k_i^{-1}}
$$

Substituting eq.(3-24) into eq.(3-27),

$$(3\text{-}28) \qquad S_i^A = \frac{\left[\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^v\right] k_i^{-1}}{\sum_{i=1}^{n} \left[\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^v\right] k_i^{-1}}$$

Now, the total actual cost equation (3-25) and the actual cost share equations (3-28) will be estimated with the above restrictions on parameters. Since the sum of cost shares is equal to 1, one of the share equations will be dropped in estimating the set of equations. The results of the estimation will be invariant to the choice of equation to be dropped.

Parametric Test for Relative Efficiency

In evaluating the relative efficiency of publicly-owned and privately-owned utilities, it is notable that economic efficiency can be interpreted and tested by various methods, and, therefore, the difficulties with the studies on efficiency are both conceptual and empirical.

Before we consider the relative efficiency of publicly-owned and privately-owned utilities, it is necessary to avoid confounding the effects of differences in technology with those of differences in firm's performance, so that we will use dummy variables in the linear terms of the shadow cost function to allow for possible differences in technology.

$$\alpha_i^r = a_i + b_i D^r$$

$$(3\text{-}29) \qquad \alpha_Q^r = a_Q + b_Q D^r$$

$$\alpha_Z^r = a_Z + b_Z D^r$$

where r = G for publicly-owned utilities, r = P for privately-owned utilities, thus, $D^G = 1$ and $D^P = 0$. We will estimate parameters, a_i, b_i, a_Q, b_Q, a_Z, and b_Z.

Concerning price efficiency, Atkinson and Halvorsen (1980) distinguished relative price efficiency and absolute price efficiency as follows. Relative price efficiency will be attained if marginal rates of technical substitution are equal to the corresponding ratios of input market prices, and absolute price efficiency will be attainted if the value of marginal product for each input is equal to the input's market price. Relative price efficiency implies that output is produced at minimum cost, while absolute price efficiency implies both cost minimization and production of the optimal quantity of output--that is, profit maximization. Returning to the above equations, the differences in price efficiency by ownership types are reflected in the coefficients, k_i's. Relative price efficiency with respect to inputs i and j will be attained if and only if $k_i = k_j$, while absolute price efficiency will be attained if and only if $k_i = 1$ for all inputs i.

On the other hand, in our case, the total actual cost equation, (3-25), and the actual cost share equations, (3-28), are homogeneous of degree zero in the k_i's.[17] Therefore, we cannot estimate the absolute values of the k_i's, so that we cannot use our generalized cost function to test for absolute price efficiency. However, since we can estimate the relative values of k_i's after an appropriate normalization, we can use our generalized cost function to test for relative price efficiency. Thus, in our context, relative price efficiency with respect to three inputs (K, L and F) will be attained if and only if $k_K = k_L = k_F$, where K, L and F reflect capital, labor and fuel, respectively.

As stated above, in developing the concept of shadow price and deriving the total actual cost equation and the actual cost share equations, the k_i's were firm-specific and input-specific. However, since separate values of the k_i's cannot be identified for each firm, the sample is divided into two groups--publicly-owned and privately-owned--according to ownership types, and the restriction that the values of k_i's are identical within each group is imposed. As a result, the estimates of k_i's for each group can be interpreted as estimates of their mean values, and the difference in estimates for each group reflects the difference in performance between publicly-owned and privately-owned utilities.

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[17] These equations are homogeneous of degree zero in the k_i's or k_j's, not in both the k_i's and k_j's.

Dummy variables are used to distinguish the values of k_i's for publicly-owned and privately-owned utilities.

(3-30) $$k_i^r = d_i + g_i D^r$$

where r = G for publicly-owned utilities, r = P for privately-owned utilities, thus, $D^G = 1$ and $D^P = 0$. The parameters, d_i and g_i, are estimated.

As stated before, since the total actual cost equation and the actual cost share equations are homogeneous of degree zero in the k_i's, we need to incorporate at least one normalization on the k_i's in order to determine economically these k_i's (Diewert, 1974). In other words, to estimate the relative values of k_i's, we have to normalize the value of one of the k_i's. It is also notable that the choices of which k_i to normalize and which value to assign to k_i do not affect the estimates of the relative values of k_i's as well as the estimates of all other parameters. From eq.(3-30), we normalize as follows,

(3-31) $$k_L^r = 1$$

which was done by setting $d_L = 1$, $g_L = 0$.

With this normalization and the definition of relative price efficiency, we will have the restrictions to attain the relative price efficiency with respect to other inputs. In our case, the relative price efficiency with respect to inputs K, L and F, will be attained if and if only $k_K = k_L = k_F$.

Thus, since $D^P = 0$, the restriction for price efficiency of privately-owned utilities is,

(3-32) $d_K = d_F = 1$

Since $D^G = 1$, the restriction for price efficiency of publicly-owned utilities is,

(3-33) $d_K + g_K = d_F + g_F = 1$

In addition to the relative price efficiency, firms should also be technically efficient to attain cost efficiency--that is, firms should produce the maximum output from any given set of inputs. To check this, a dummy variable is incorporated in the intercept term to allow for differences in technical efficiency of publicly-owned and privately-owned utilities.

(3-34) $\alpha_0^r = d_0 + g_0 D^r$

Economies of Scale

Since most studies indicate that there exist economies of scale in electric power generation, if publicly-owned and privately-owned utilities are different in size, this could affect the estimation of their relative efficiencies. Economies of scale are usually defined in terms of the relative increase in output resulting from a proportional increase in all inputs. However, Hanoch (1975) noted that it is more relevant to measure returns to scale by the relationship between total cost and output along the expansion path--where input prices are constant and costs are minimized at every level of output.

Following Hanoch's concept, Christensen and Greene (1976) expressed the extent of scale economies--that is, local measure of returns to scale--as the proportional increase in cost resulting from a small proportional increase in output, or as the elasticity of total cost with respect to output.

Two kinds of returns to scale can be considered because of two kinds of total cost--total actual cost and total shadow cost. According to Atkinson and Halvorsen (1984), the relationship between total actual cost and output is relevant for evaluating the optimum scale of firms from the view of public policy. On the other hand, the relationship between total shadow cost and output is relevant for evaluating the optimal scale of firm from the firm's managers' view.

Therefore, the elasticity of total actual cost with respect to output is,

$$\frac{\partial \ln C^{A}}{\partial \ln Q} = \alpha_{Q} + \beta_{QQ} \ln Q + \sum_{i=1}^{n} \beta_{iQ} \ln (k_i p_i) + \beta_{Qz} Z^{v}$$

$$+ \frac{\sum_{i=1}^{n} k_i^{-1} \beta_{iQ}}{\sum_{i=1}^{n} k_i^{-1} [\alpha_i + \sum_{j=i}^{n} \beta_{ij} \ln(k_j p_j) + \beta_{iQ} \ln Q + \beta_{iz} Z^{v}]} \qquad (3\text{-}35)$$

While the elasticity of total shadow cost with respect to output is given by eliminating the last term in eq.(3-35).

Thus, the elasticity for total actual cost will be larger (or smaller) than the elasticity for total shadow cost, if the last term in eq.(3-35) is positive (or negative).

Now, define scale economies, SE, as unity minus the above elasticity.

(3-36)
$$SE^{A} = 1 - \frac{\partial \ln C^{A}}{\partial \ln Q}$$
$$SE^{S} = 1 - \frac{\partial \ln C^{S}}{\partial \ln Q}$$

Since estimates of scale economies are usually expressed as a percentage, SE^{A} and SE^{S} would be multiplied by 100. The positive numbers represent positive scale economies and negative numbers represent scale diseconomies.

Scale economies are independent of factor prices if and only if the production function is homothetic. Although the translog cost function does not constrain the structure of production to be homothetic, these homotheticity restrictions can be tested statistically. Christensen and Greene (1976) noted that a cost function corresponds to a homothetic production function if and only if the cost function can be written as a separable function in factor prices and output. Therefore, the homotheticity restrictions on the translog cost function are,

(3-37) $\beta_{iQ} = 0$

They also noted that a homothetic production function is further restricted to be homogeneous if and only if the elasticity of cost with respect to output is constant. Therefore homogeneity restrictions are,

(3-38) $$\beta_{iQ} = 0\ , \qquad \beta_{QQ} = 0$$

Elasticities of Demand and Substitution

The own-price elasticity of demand for input i with respect to its market price is,

(3-39) $$E_{ii} = \frac{\partial X_i}{\partial P_i}\frac{P_i}{X_i}$$

Substituting X_i of eq.(3-17) into eq.(3-39),

(3-40) $$E_{ii} = \frac{S_i^s(S_i^s - 1) + \beta_{ii}}{S_i^s}$$

And, the cross-price elasticity of demand is,

(3-41) $$E_{ij} = \frac{\partial X_i}{\partial P_j}\frac{P_j}{X_i} = \frac{S_i^s S_j^s + \beta_{ij}}{S_i^s}$$

Next, the Allen partial elasticity of substitution (Allen, 1938) can be computed as follows,

(3-42) $$\sigma_{ij} = \frac{1}{S_j^s}E_{ij} = 1 + \frac{\beta_{ij}}{S_i^s S_j^s}$$

CHAPTER 4
THE DATA USED IN THE EMPIRICAL ANALYSIS

Introduction

The electric power industry can be conventionally subdivided into three components--generation, transmission, and distribution. We confine our attention to the generation component.

The major types of electricity generation in the U.S. are steam-electric, hydro-electric, and nuclear-electric generation. Since the technology, cost, and input substitutability of these types of electricity generation are quite different, we also confine our attention to steam-electric generation.

Next, in our empirical model, output is specified to be a function of three inputs--capital, X_K, labor, X_L, and fuel X_F.

Method of Data Construction

To estimate the empirical model, the data on the following variables are required.

1. Total production costs and the shares in total cost of the three components--capital, labor, and fuel.
2. Output.

3. The price of capital.
4. The price of labor.
5. The price of fuel.
6. A dummy variable for different types of ownership--publicly-owned and privately-owned electric utilities.
7. A dummy variable for different types of market structure--monopolistic and competitive environments.

The cross section data of 182 firms--121 privately-owned and 61 publicly-owned--in the year 1986 were used in the analysis. The selection of 182 firms was made primarily on the basis of data availability for steam-electricity generation. Missing data on the individual variables reduced the sample still further. Generally, the data for publicly-owned utilities were poorer than privately-owned. For example, compared with privately-owned utilities, the relatively small number of publicly-owned utilities was due to the inaccessibility of data on wages and employment. These data were obtained from mail questionaire sent to publicly-owned utilities. 61 out of 91 companies returned the questionaire.

The data construction, with several exceptions, follows the method used by Atkinson and Halvorsen (1986), who followed Nerlove's work (1963). Unless otherwise indicated, the data used in the empirical analysis were mainly obtained from Financial Statistics of Selected Electric Utilities 1986 (1988), Electric Power Quarterly (1986, 1987), Cost and

Quality of Fuels for Electric Utility Plants 1986 (1987), and Historical Plant Cost and Annual Production Expenses for Selected Electric Plants 1986 (1988).

Total Production Cost

It is assumed that total production cost consists of the annual capital cost, labor cost, and fuel cost of production.

Capital cost of production

Before we define capital costs, it is necessary to note that, unlike the data for labor and fuel costs, capital costs have to be estimated, and thus, an accounting imputation is required.

In constructing a rough proxy for capital cost, Nerlove (1963) and Atkinson and Halvorsen (1986) summed just interest expenses and depreciation. Then, interest and depreciation charges on the firm's entire production plant were multiplied by the ratio of the firm's book value of steam production plant to the book value of total production plant.

In our study, we followed their procedures except the following. We summed interest expenses, depreciation and amortization charges (instead of interest expenses and depreciation charges) reported by the firm.[18]

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[18] "Depreciation" means charges made against income for distributing the cost of depreciable plant, so as to allocate it equitably across the period in which services are obtained from the use of facilities. On the other hand, "Amortization" means the gradual write-off of an amount recorded in an account over a predetermined period, such as the remaining life of a particular asset or liability. In addition, the

On the other hand, although Nerlove and Atkinson and Halvorsen have employed the above procedure to calculate capital cost, they also recognized several problems about its adequacy. Several shortcomings noted by them are as follows. First, interest and depreciation charges do not reflect capital costs as defined in an economically meaningful way. For example, the most severe shortcoming is that the part of capital financed by equity is ignored. Second, depreciation practices chosen by firms have considerable variation from firm to firm, because there are about four basic methods in use by electric utilities. Third, this procedure assumes that steam and hydraulic plants depreciate at the same rate, which is clearly unjustifiable. Fourth, they did not adjust for differences in the vintage of capital. Nevertheless, there is no practical alternative.

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write-off may occur over a period during which the utility has anticipated a related benefit or is going to recognized an obligation (Historical Plant Cost and Annual Production Expenses for Selected Electric Plants, 1986). A more detailed explanation of the accounting differences between depreciation and amortization is as follows. Besides the depreciable plant assets, there are other types of resources that have no physical substance but firms expect also will provide benefits for more than one year--for example, patents, copyrights, trademarks, and goodwill. These intangibles are also characterized as assets, and must be amortized over the periods benefited. Thus, the amortization is the process of matching the cost of intangible assets against revenue over those periods (Intermediate Accounting, 1989). Depreciation and amortization are only given as a summed cost in the data on publicly-owned utilities. For privately-owned utilities, these costs are reported separately and are summed to produce total cost.

Labor cost of production

More detailed data were available for the privately-owned utilities. That is, in case of the privately-owned utilities, total salaries and wages for each stage of production are given for both operation and maintenance expenses.

However, although we have looked into all the volumes published by the Energy Information Administration, we have been unable to find any wage and employment data for the publicly-owned utilities. Thus, we sent a mail questionaire to collect wage and employment data for the publicly-owned utilities in the year 1986.[19]

Next, if steam-electric generation was not the only type of generation employed by the firm, the total labor expenditure was multiplied by the ratio of steam production to total production. That is, we assumed that the ratio of output to labor was equal for all types of generation.

Fuel cost of production

Fossil fueled steam-electric generation has used coal, oil, and gas as fuel. The data for amounts of fuel are given by short tons, barrels, and cubic feet. The cost data for fuel are described by cent per million BTU and dollars per short ton, barrel, and thousand cubic feet.[20] Fuel expenditure was directly calculated by summing each type of fuel cost.

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[19] The questions are as follows:
1) name of company.
2) 1986 total salaries and wages charged to elcctric operation and maintenance.
3) 1986 number of regular full-time employees.
4) 1986 number of part-time and temporary employees.

The shares in total cost

The relative shares in total cost were easily calculated by dividing each cost of three components into total cost.

Output

For privately-owned utilities, we can directly obtain the net output by steam-electric generation from the Financial Statistics of Selected Electric Utilities (1986). But, for publicly-owned utilities, only the total amount by all types of generation--not each type of generation--is presented.

On the other hand, Electric Power Quarterly (1986) contains monthly net steam-electric generation at every plant level of both publicly-owned and privately-owned utilities by each type of fuel. Thus these data were utilized to obtain annual total output for both types of utilities.

It would be useful to consider load factor, which is the ratio of average consumption to peak consumption, since this would help to measure the effect of variable output on costs. However, the data on the load factor are not available.

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[20] The costs reported by electric utilities include all costs incurred by the utility (including transportation, taxes, etc) for delivery of fuel to the electric plant (Cost and Quality of Fuels for Electric Utility Plants, 1986).

Price of Capital

It can be said that measuring the price of capital is nearly as difficult as measuring the cost of capital. Nerlove (1963) and Atkinson and Halvorsen (1986) measured the price of capital as the current yield on the firm's latest issue of long term debt multiplied by Handy-Whitman Index of Electric Utility Construction Costs.

Apart from the imperfection in measuring the price of capital, Nerlove mentioned that the primary shortcomings of this measure are as follows. First, this measure ignores the possibility of other method of financing--especially, equity financing--electric utility construction. Second, the Handy-Whitman Index includes the construction costs of hydraulic installations.

As to the firm's latest long term debt, we chose the bond issued closest to July, 1986, and mainly chose thirty year bonds with twenty or more years to maturity. These were obtained from Moody's Public Utility Manual.

However, utilities issue long term bonds infrequently. Furthermore, since the corresponding interest rates fluctuate over time, this induces undesired variability into the measured price of capital. To rectify this situation, interest rates are adjusted for differences in the interest rate over time. We have used the yield of Treasure long term bond issued at July, 1986 as the standard yield to be adjusted. For example, Alabama Power Company issued a thirty year bond to maturity with a 9.375% interest rate in May, 1986. On the other hand, the yields of Treasury long term bonds issued at May, 1986 and at July, 1986 are 8.09% and 7.88%, respectively. Then, the adjusted yield for Alabama Power Company will be 9.165, which equals 9.375+(7.88-8.09).

On the other hand, the Handy-Whitman Index numbers are constructed by dividing the U.S. into only six regional divisions. For more detailed index numbers, we used the Means City Cost Index, which gives us the construction cost index numbers state by state. These figures were multiplied by the current yield on the utility's latest issue of long term debt.

Price of Labor

As stated before, we obtained wage and employment data for the publicly-owned utilities in the year 1986 from a mail questionaire. For all utilities, the total number of employees was found by summing the number of full-time employees and one half the number of part-time employees. The price of labor is then estimated as the ratio of total labor cost to total number of employees. This implicitly assumes that all employees in each category work the same number of hours and, on average, have the same quality.

Price of Fuel

As stated before, data for fuel consumption are given in detail. Since three kinds of fossil fuel--coal, gas, and oil--are used for steam-electric generation, these prices of fuel were taken on a per British Thermal Unit (BTU) basis to avoid the problem of aggregating three kinds of fuel. Thus the unit of price of fuel is dollars per million BTU.

The price of fuel was calculated as a BTU-weighted-average of the prices of three kinds of fuel used by each firm. We obtained most of the data from Cost and Quality of Fuels for Electric Utility Plants 1986 (1987). But, for the five firms for which these data were not available from this source, we use Historical Plant Cost and Annual Production Expenses for Selected Electric Plants 1986 (1988).

One shortcoming of this measure is that it does not consider a BTU to KWH conversion factor for the each type of fuel. That is, the amount of BTU used for generating one KWH of electricity is different with each type of fuel. However, we have not found figures which would enable us to make this adjustment.

Dummy Variable for Different Ownership

The U.S. electric power industry is a combination of privately-owned, publicly-owned, cooperative, and Federal utilities.[21] Compared with privately-owned utilities, publicly-owned, cooperative, and Federal utilities play a secondary role. These utilities are small, and usually are financed through governmental and/or nonprofit financial organization. They have a preference in the purchase of less expensive Federal power (Financial Statistics of Selected Electric Utilities 1986, 1988). In our study, we will confine our attention to privately-owned and publicly-owned electric utilities. As a result, our data consist of 121 privately-owned and 61 publicly-owned electric utilities.

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[21] Rural electric cooperatives operate in 46 States and represent 30 percent of the total number of electric utilities in the industry. The Federal Government is primarily a water-power generator and wholesaler of electricity, rather than a distributor to ultimate consumers.

Privately-owned electric utilities have served the large consolidated markets where economies of scale afford the lowest prices. In 1986, 282 privately-owned utilities, or 9 percent of the total number of electric utilities in the industry, accounted for 79 percent of all revenues from sales to ultimate consumers and 37 percent of all revenues from sales for resale. Privately-owned utilities operate in all States except Nebraska. Hawaii is the only State in which all electricity is supplied by privately-owned utilities (Financial Statistics of Selected Electric Utilities 1986, 1988).

The publicly-owned electric utilities in our sample used here include municipals, public power districts, State authorities, irrigation districts, and other State organizations.

Dummy Variable for Market Structure

It was surprisingly difficult to determine whether competition exists in the electric power industry. In an interesting paper, Primeaux (1977)argued that economists have usually overlooked the fact that there are electric utility duopolies in the U.S.[22] In all duopoly cities, the publicly-owned utility generally competed with the privately-owned utility. However, in various states, competition between the two firms appeared in different ways. In some states, a customer could switch electric utilities at will. In other states, a new customer could choose his utility, but once chosen, the customer could not switch. Primeaux (1977) argued that regardless of the specific arrangement, direct competition existed in these duopoly cities.

However, those kinds of competition between the two firms in duopoly cities does not reflect the current situation of the overall electric utility industry in the U.S. That is, this kind of duopoly is rare and not susceptible to analysis. Thus, we seek to identify other factors which can be used to classify local electric utilities into two market structures--monopoly and competition.

Fortunately, we found a helpful paper by Primeaux, Filer, Herren, and Hollas (1984). Studying a regulatory policy toward competition in the electric utility industry, they suggested that a fairly objective measure of hostile policy toward competition can be obtained by looking at the combination of gas and electric utilities in the states. They also quoted Sam Peltzman's suggestion. According to Peltzman, gas utilities and electric utilities produce substitutes. That is, gas and electricity can each be used to provide heat, hot water, or to cook. In some places, a combined (gas and electricity) firm supplies both of them, while elsewhere separate firms supply gas or electricity respectively. Therefore, there is no competition if one firm supplies both electricity and gas.

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[22] Primeaux (1977) argued this on the basis of Brown's (1969) correspondence to him.

By employing their logic, a firm is classified as a monopoly if it supplies both gas and electricity and as a competitor if it supplies only electricity. On the other hand, the dummy variable employed in our study may be correlated with any economies of scope, since the combined firms defined as monopoly produce multiple products.[23] Actually, electric utilities provide examples of the potential for economies of scope. For example, in the generation stage, day and night electricity supplies can be regarded as separate products with strong cost complementarities. In addition, the supplies of electricity to more than one community may entail efficiencies at the distribution stage. The list of combined firms is obtained from the Electrical World: Directory of Electric Utilities (1986-1987).

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[23] Economies of scope captures the essence of multiproduct versus single-product production. It contrasts the cost of producing outputs $q_1,...,q_n$, all in a single firm, with the total cost of producing each output q_i, $i = 1,...,n$, in separate firms, each specializing in the production of one product (Berg and Tschirhart,1988).

As a result, our data consist of 127 competitive electric utilities, and 55 monopolistic electric utilities.

Summary

We are going to show some descriptive statistics for the entire sample used for our empirical study. Table 4-1 contains each variable's minimum, maximum, mean, and standard deviation. There is clearly considerable variation across utilities in the price of inputs they face.

Now, putting all the sample together, we need to distinguish electric utilities into four categories on the basis of two dummy variables--ownership and market structure. Table 4-2 shows the number of electric utilities in four categories. First, it is clear that there are very few publicly-owned monopolies in sample. Second, almost one half of the utilities are privately-owned firms operating in a competitive market.

Table 4-3 represents means for each variable of the four categories. According to the figures of Table 4-3, privately-owned utilities produce much more than publicly-owned utilities. The price of capital is lower to the publicly-owned utilities than to the privately-owned utilities, reflecting the favorable tax status given to municipal bonds. Electric utilities in monopoly environment face higher price of labor than in competitive environment, perhaps because the incentive to fight union wage gains is higher in a competitive environment. On the other hand, utilities in monopoly environment face lower price of fuel than in competitive environment.

Table 4-1
Descriptive statistics for the entire sample

Variable	Minimum	Maximum	Mean	Standard Deviation
Total cost ($)	2,196,917	2,286,818,759	284,323,672	352,962,621
Output (MWH)	16,688	75,450,682	8,178,322	11,082,746
Price capital	478.17	1,232.92	793.63	151.05
Price labor ($)	14,103.77	46,393.12	25,734.44	5,185.12
Price fuel[1] ($/million BTU)	0.672934	4.912121	1.8951966	0.5322521
Share capital	0.015614	0.793253	0.3378822	0.1538029
Share labor	0.031222	0.526457	0.1823392	0.0906538
Share fuel	0.051298[2]	0.90124	0.4797786	0.1817249

Note: [1] Since the individual plants of utilities use the different types of fuel, the price of fuel might be related to the share of capital in a systematic way.
[2] The minimum value of the share of fuel is much smaller than the maximum value. This might be attributable to stockpiling of fuel over time, since the data for fossil fuels used here are the receipts data.

Table 4-2
The number of electric utilities in four categories

	Privately-owned	Publicly-owned
Competition	75	52
Monopoly	46	9

Table 4-3
Means for Each Variable of the Four Subsamples

Variable	Means Private Competition	 Private Monopoly	 Public Competition	 Public Monopoly
Total cost	428,458,050	333,268,727	68,944,651	77,452,355
Output	13,281,927	8,751,964	1,429,710	1,708,307
Price capital	866.73	873.08	649.66	610.11
Price labor	25,707	25,982	25,367	26,807
Price fuel	1.891174	1.786720	2.025360	1.731085
Share capital	0.302866	0.337615	0.374904	0.417143
Share labor	0.163414	0.181365	0.207267	0.200996
Share fuel	0.533719	0.481019	0.417829	0.381861

CHAPTER 5
EMPIRICAL RESULTS

Before we discuss our empirical results, we will start out by presenting the translog cost function and share equations which are estimated.

$$\begin{aligned} \ln C^{A} = {} & \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(k_i p_i) + \alpha_Q \ln Q + \alpha_Z Z^{V} \\ & + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln(k_i p_i) \ln(k_j P_j) \\ & + \frac{1}{2}\beta_{QQ} (\ln Q)^2 + \sum_{i=1}^{n} \beta_{iQ} \ln(k_i p_i) \ln Q \\ & + \sum_{i=1}^{n} \beta_{iZ} \ln(k_i p_i) Z^{V} + \beta_{QZ} (\ln Q) Z^{V} \\ & + \ln\{\sum_{i=1}^{n} k_i^{-1} [\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) \\ & + \beta_{iQ} \ln Q + \beta_{iZ} Z^{V}]\} \end{aligned} \tag{3-25}$$

$$S_i^{A} = \frac{\left[\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^{V}\right] k_i^{-1}}{\sum_{i=1}^{n} \left[\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln(k_j P_j) + \beta_{iQ} \ln Q + \beta_{iZ} Z^{V}\right] k_i^{-1}} \tag{3-28}$$

The total actual cost equation (3-25) and the actual cost share equations (3-28) are estimated with the restrictions, eq.(3-21), on linear homogeneity in shadow prices. The equations are estimated by non-linear least squares.

We incorporate eq.(3-29) to distinguish the difference in technology from the difference in behavior. For parametric efficiency tests, we normalize one of k_i's, and also incorporate eq.(3-30) to distinguish the values of k_i's for different ownership and eq.(3-34) to allow the difference in technical efficiency.

Different Model Specification: Cobb-Douglas Function

Now, we will consider the adequacy of our empirical model constructed in chapter 3. The translog functional form contains many interacting terms which may or may not affect the estimation results. As we will describe later, the estimation results appeared that many of the parameters were insignificant. In particular, this was true for many of the interaction terms. This might suggest that electricity costs can be adequately described by a simpler model rather than the translog functional form. One possibility is the Cobb-Douglas functional form which does not require the interaction terms and square terms.

When we apply the Cobb-Douglas production function, the shadow costs defined in eq.(3-13) have the form;

$$(5\text{-}1) \qquad \ln C^{S} = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(k_i p_i) + \alpha_Q \ln Q + \alpha_Z Z^{V}$$

This shadow cost function should be homogeneous of degree one in shadow prices, and this is done when the following restriction is satisfied,

$$\sum_{i=1}^{n} \alpha_i = 1 \tag{5-2}$$

The shadow cost share equations are,

$$S_i^s = \alpha_i \tag{5-3}$$

Next, the corresponding actual cost function and the actual cost share equations are,

$$\begin{aligned} \ln C^A &= \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(k_i p_i) + \alpha_Q \ln Q + \alpha_Z Z^V \\ &\quad + \ln \sum_{i=1}^{n} k_i^{-1} \alpha_i \end{aligned} \tag{5-4}$$

$$S_i^A = \frac{\alpha_i k_i^{-1}}{\sum_{i=1}^{n} \alpha_i k_i^{-1}} \tag{5-5}$$

Imposing the restriction in eq.(5-2), the set of equations to be estimated are eq.(5-4) and eq.(5-5).[24]

Alternatively, without estimating these equations, the validity of the Cobb-Douglas functional form can be tested from the estimation results of the translog functional form, because the Cobb-Douglas is a special case of the translog. That is, given the estimation results based on the translog functional form, we can test the hypothesis that all the interaction terms and the square terms are restricted to zero. Thus, the null hypothesis in a test of the validity of the Cobb-Douglas is given as follows.

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[24] Unfortunately, the estimates did not converge. This might be due to an inability to choose the appropriate starting (initial) values for running the Cobb-Douglas.

$$H_0 \quad : \quad \beta_{KF} = \beta_{KL} = \beta_{LF} = \beta_{QQ} = \beta_{KQ} = \beta_{LQ} = \beta_{KZ} = \beta_{LZ} = \beta_{QZ} = 0 \tag{5-6}$$

The Wald test can be used to test the above hypothesis. If the above hypothesis is rejected, then the Cobb-Douglas functional form is inappropriate. Based on the estimation results below, the result of the Wald test for the hypothesis that the given set of coefficients is jointly zero is as follows.

Chi-squared value = 129.23819

Since the critical value of the Chi-square distribution with 9 degrees of freedom at the 5% significance level is 16.9190, the null hypothesis is rejected. Thus, in our context, the translog cannot be replaced by simpler Cobb-Douglas function.

Relative Efficiency

As discussed in chapter 3, the total actual cost equation (3-25) and the actual cost share equation (3-28) are estimated under the restrictions given there. The estimation results are mentioned in table 5-1.

First, we will consider whether publicly-owned and privately-owned electric utilities have equal cost efficiency. The Likelihood Ratio test will be used for this hypothesis.

We have already normalized the value of k_i's to estimate the relative values of k_i's. That is,

$$k_L^r = 1$$

From this normalization and eq.(3-30), the restrictions for equal price efficiency are,

(5-7) $$g_K = 0 , \qquad g_F = 0$$

Besides the restrictions on equal price efficiency, an additional restriction for equal technical efficiency is required for equal cost efficiency. From eq.(3-34), the restriction for equal technical efficiency is,

(5-8) $$g_0 = 0$$

With these restrictions, the LR test statistic is given by,

(5-9) $$\begin{aligned} LR &= -2\,[L(\theta_r) - L(\theta_u)] \\ &= -2\,(319.243 - 333.949) \\ &= 29.412 \end{aligned}$$

Where $L(\theta_r)$ is the maximum of the Log-likelihood function with the restrictions, and $L(\theta_u)$ is the maximum of the Log-likelihood function without any restrictions.

Table 5-1
Estimation Results

Parameter	Estimate	Parameter	Estimate
d_0	14.9047* (1.4689)	b_Q	0.2614* (0.0504)
g_0	-2.8694* (0.7742)	a_Z	0.3664 (0.4249)
a_K	0.4810* (0.1250)	b_Z	-0.0244 (0.1356)
b_K	-0.1024 (0.1220)	β_{KL}	-0.0234 (0.0414)
a_L	0.0725 (0.0820)	β_{KF}	-0.1030* (0.0257)
b_L	-0.0356 (0.0652)	β_{LF}	-0.0033 (0.0115)
d_K	6.4877 (13.9498)	β_{KQ}	-0.0347* (0.0129)
g_K	0.9297 (4.0030)	β_{LQ}	-0.0048 (0.0096)
k_L	1.0000	β_{QQ}	0.1165* (0.0131)
d_F	0.9423 (1.8697)	β_{KZ}	0.0297* (0.0177)
g_F	4.8413 (9.8914)	β_{LZ}	-0.0031 (0.0072)
a_Q	-0.8006* (0.2138)	β_{QZ}	-0.0288 (0.0274)
a_F	0.4465* (0.1122)	b_F	0.1379 (0.1178)

Table 5-1 (continued)

Parameter	Estimate	Parameter	Estimate
β_{KK}	0.1265* (0.0400)	β_{LL}	0.0267 (0.0503)
β_{FF}	0.1063* (0.0241)	β_{FQ}	0.0395* (0.0099)
β_{FZ}	-0.0265 (0.0157)		

Log Likelihood = 333.949
Number of observation = 182
R-square of total actual cost equation = 0.9409
R-square of share of capital = 0.188163
R-square of share of labor = 0.310279

Notes: 1) Standard Errors are in parentheses.
2) $\alpha_0 = d_0 + g_0 * D^r$
3) $\alpha_K = a_K + b_K * D^r$
4) $\alpha_L = a_L + b_L * D^r$
5) $\alpha_F = 1 - \alpha_K - \alpha_L$
6) $k_K = d_K + g_K * D^r$
7) k_L is constrained to equal to 1.0.
8) $k_F = d_F + g_F * D^r$
9) $\alpha_Q = a_Q + b_Q * D^r$
10) $\alpha_Z = a_Z + b_Z * D^r$
11) $\beta_{FQ} = -(\beta_{KQ} + \beta_{LQ})$
12) $\beta_{FZ} = -(\beta_{KZ} + \beta_{LZ})$
13) *: significant at the 5% level.

Since the critical value for the chi-square distribution with 3 degrees of freedom at the 5% significant level is 7.81, the null hypothesis of equal cost efficiency between publicly-owned and privately-owned electric utilities is rejected.

This result is different from the results of Färe, Grosskopf and Logan (1985), and Atkinson and Halvorsen (1986). Both of those studies concluded that there is no significant difference in efficiency between publicly-owned and privately-owned electric utilities. Furthermore, Atkinson and Halvorsen (1986) concluded that the two types of electric utilities in the U.S. are equally cost inefficient.

There are several reasons for the different results. First, we incorporated the market variable, even if the estimates appeared insignificant. Second, we used a larger sample of public-owned utilities. Third, we used better variables for the price of capital and the price of labor. We will show later how our results are different from theirs.

We consider the t-statistics of the parameter estimates in table 5-1. First of all, the estimates of parameters, d_0 and g_0, and a_Q and b_Q, are significant at 5% level. These parameters correspond to the intercept term and output (lnQ) terms. Based on the significant coefficients of these parameters on these terms, we can assume that the unequal cost efficiency between publicly-owned and privately-owned utilities might be associated with the amount of output. Now, in order to find the relation between total cost and output, we substitute the above estimates of parameters and the mean values of input prices into each ownership type's actual total cost function respectively. We ignore the square term and several terms including the market variable, because the square term, $\frac{1}{2}\beta_{QQ}(\ln Q)^2$, does not affect the difference in total actual cost between publicly-owned and privately-owned utilities, and the estimates of parameters reflecting the market structures are insignificant. Here, it is notable that if we ignore the square term, total costs decrease when the amount of output increases, because the parameters, a_Q, β_{KQ}, β_{LQ} and β_{QZ}, reflecting output except β_{FQ} are negative.[25] But, since the parameter, β_{QQ}, of square term is significant and positive, and $\frac{\partial \ln C^A}{\partial \ln Q} > 0$, if we consider the square term, total costs increase when output increases. Furthermore, the positive sign of β_{QQ} means that scale diseconomies exist at some points as we will describe later. In the case of publicly-owned utilities,

$$\ln C_G^A = 19.0477 - 0.7856 \ln Q + \ln(0.2204 - 0.0027 \ln Q) \tag{5-10}$$

In the case of privately-owned utilities,

$$\ln C_P^A = 23.5864 - 1.1271 \ln Q + \ln(-0.2319 + 0.0318 \ln Q) \tag{5-11}$$

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[25] The sign of parameter b_Q is positive, but its absolute value is less than that of parameter, a_Q.

The difference in total actual cost between publicly-owned and privately-owned utilities is,

$$\ln C_G^A - \ln C_P^A = 4.5387 - 0.3415 \ln Q \qquad (5\text{-}12)$$
$$+\ln(-0.2319 + 0.0318 \ln Q)$$
$$-\ln(0.2204 - 0.0027 \ln Q)$$

Publicly-owned utilities have higher, lower, or equal total costs relative to privately-owned utilities, if this difference is greater than, less than, or equal to zero. We can also illustrate these cases graphically. Figure 5-1 which graphs total cost as a function of output presents the difference in total cost between publicly-owned and privately-owned utilities. To find Q^* in figure 5-1,

let
$$4.5387 - 0.3415 \ln Q$$
$$+ \ln(-0.2319 + 0.0318 \ln Q)$$
$$- \ln(0.2204 - 0.0027 \ln Q) = 0$$

then, $Q^* = 725{,}106$

Therefore, in case of generating more electricity than 725,106 mwh, publicly-owned electric utilities have higher AC--that is, privately-owned electric utilities are more cost efficient. But, in case of generating less electricity than 725,106 mwh, privately-owned electric utilities have higher AC--that is, publicly-owned electric utilities are more cost efficient.

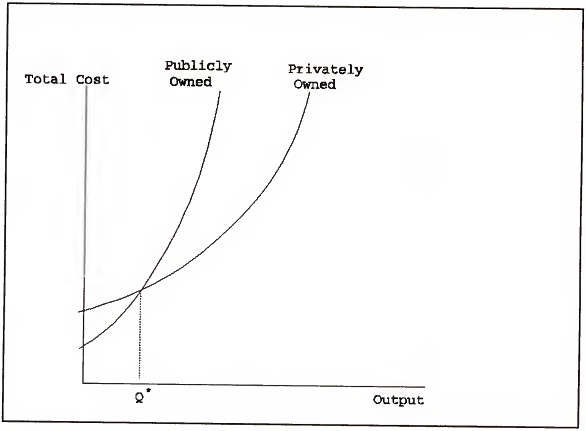

Figure 5-1 : Comparison in Total Cost between Publicly- and Privately-owned electric utilities

In 1986, fifty four electric utilities generated less than 725,106 mwh electricity. This includes forty two publicly-owned utilities (sixty nine percent of that sample) and twelve privately-owned utilities (ten percent of that sample).

Finding that publicly-owned utilities are relatively more efficient at small output levels supports the hypothesis that monitoring of public jurisdictions is more efficient in small cities, where the individual is more likely to have an impact on the output.

Before we go further, there is one more thing to be considered. Since the parameters in intercept term and output term of eq.(5-13) might be correlated, it is desirable to ascertain in what range of output the above difference is significantly negative and significantly positive. That is, this can be found from the 95% confidence interval for the above difference. But, since we cannot get an analytical solution for Q from eq.(5-12), we cannot easily calculate the confidence interval.

Now, we will go through the estimate results variable by variable. The estimates of parameters, d_K and g_K, and d_F and g_F, are not significant at the 5% level. Those are come from k_K and k_F respectively. As stated in chapter 3, since we normalized k_L^r as unity, relative price efficiency for privately-owned utilities is attained when $d_K = d_F = 1$, and relative price efficiency for publicly-owned is attained when

$d_K + g_K = d_F + g_F = 1$. On the other hand, t-tests accept the hypotheses that $d_k = 1$ and that $d_f = 1$ for privately-owned utilities, and that $d_K + g_K = 1$ and that $d_F + g_F = 1$ for publicly-owned utilities.

Contrary to our expectations, the estimates of parameters, a_Z, b_Z, β_{LZ}, β_{FZ}, and β_{QZ}, which reflect different market structures, all except β_{KZ} turned out to be insignificant at the 5% level. On the face of it, this evidence suggests that market structure does not affect cost. There is, however, an alternative explanation. As we mentioned in chapter 4, since the combined firms defined as monopoly produce multiple products--electricity and gas, the dummy variable employed for competition and monopoly may be correlated with any economies of scope. If the cost increases accompanied by monopoly are offset by the cost decreases due to economies of scope, the parameters of dummy variable reflecting different market structures may be insignificant. Also, the pressures from competition may be smaller in the regulated environment the utilities face. Let us now turn to the only significant parameter, β_{KZ}, which has a positive coefficient. This provides the same evidence that capital expenditures are higher in a monopoly market. Monopoly is much more common among privately-owned utilities, which face a higher price of capital.

The estimates of parameters, b_K, a_L, b_L, and b_F reflecting input and firm specific shadow prices are also insignificant at the 5% level except the parameters, a_K and a_F, which reflect capital and fuel shadow prices of privately-owned utilities. Our results show that the parameters, α_K and α_F, are positive and do not differ by ownership.

Economies of Scale

First of all, homotheticity of production function was tested using the restrictions in eq.(3-37). Thus, the null hypothesis on homotheticity is given as follows.

(5-16) $$H_0 \quad : \quad \beta_{KQ} = \beta_{LQ} = 0$$

The Wald test is used for testing the above hypothesis. The result of Wald test for the hypothesis that the given set of coefficients is jointly zero is as follows.

Chi-squared = 16.082061

Since the critical value of Chi-square distribution with 2 degrees of freedom at the 1% significance level is 9.21034, the null hypothesis on homotheticity is rejected. Thus, expansion path is not a ray through the origin.

Although we discussed homogeneity of production function in chapter 3, we do not have to test for homogeneity any more, because homogeneity is a special case of homotheticity, and the test for homotheticity is rejected.

An estimate of scale economies can be calculated for the individual electric utilities by evaluating eq.(3-36) at the observed level of output and input prices. We selected the 10 utilities producing the smallest amount of output and the 10 utilities producing the largest amount of output. The estimates of scale economies with respect to total actual cost, SE^A, for these electric utilities are presented in the fourth column of table 5-2. The range of estimates of SE^A in our sample is from 73.2% (Banger Hydro-Electric Co., which is privately-owned and in competitive environment, generating output of 50,957 MWH) to -12.1% (Salt River Proj. Ag. I & P Dist., which is publicly-owned and in competitive environment, generating output of 17,397,426 MWH).

The negative estimates of scale economies--that is, scale diseconomies--with respect to actual cost appeared by the eight of the 182 electric utilities in our sample, and those are presented in the fourth column of table 5-3. This means that eight utilities are operating in the upward sloping portion of their actual average cost function. But, the finding that the eight utilities are operating in the upward sloping portion of their actual average cost function does not necessary imply that these utilities are operating non-optimally from the managerial view, since we assumed that the electric utilities in our sample minimize total shadow cost rather than total actual cost.

On the other hand, the estimates of scale economies with respect to total shadow cost, SE^S, are presented in the fifth column in table 5-2 and table 5-3. The range of estimates of SE^S in our sample is from 84.6% (Banger Hydro-Electric Co.) to

Table 5-2
Estimates of Scale Economies
for 10 Utilities Producing the Lowest Output
and for 10 Utilities Producing the Highest Output
(Utilities Are Ordered by Output)

Electric Utilities	Ownership and Market Structure	Output (MWH) 1986	Estimate of Scale Economies	
			SE^A	SE^S
Cedar Falls	G, M	16,688	70.6%	69.2%
Farmington	G, C	21,100	62.2%	60.8%
Henderson	G, M	23,728	66.2%	64.8%
Coffeyville	G, C	32,200	57.6%	56.2%
Burlington	G, C	36,800	53.9%	52.5%
Greenville	G, C	44,370	55.4%	54.0%
Banger Hydro-Electric Co.	P, C	50,957	73.2%	84.6%
Columbus	G, C	58,715	53.2%	51.8%
Central Nebraska Pub. P&I Dist.	G, C	61,873	49.2%	47.8%
New Ulm	G, M	62,613	53.4%	51.9%
Pennsylvania Power & Light Co.	P, C	27,950,868	6.1%	13.6%
Appalachian Power Co.	P, C	28,579,040	5.6%	13.2%
Duke Power Co.	P, C	30,255,974	4.5%	11.4%
Ohio Power Co.	P, C	33,251,253	4.0%	11.4%

Table 5-2 (Continued)

Alabama Power Co.	P, C	34,668,875	2.7%	9.6%
Pennsylvania Electric Co.	P, C	36,411,494	2.9%	10.0%
Detroit Edison Co.	P, C	37,207,384	2.9%	10.1%
Houston Lighting & Power Co.	P, C	45,444,647	-0.2%	6.7%
Georgia Power Co.	P, C	62,676,691	-3.5%	3.4%
Texas Utilities Electric Co.	P, C	75,450,682	-5.4%	1.4%

Table 5-3
Eight Electric Utilities with
Negative Economies of Scale
(Utilities Are Ordered by Output)

Electric Utilities	Ownership and Market Structure	Output (MWH) 1986	Estimate of Scale Economies	
			SE^A	SE^S
Austin	G, C	5,853,496	-1.7%	-3.3%
Los Angeles	G, C	7,203,887	-3.3%	-4.7%
South Carolina Pub. Serv. Authority	G, C	8,628,972	-6.1%	-7.7%
San Antonio	G, M	10,560,712	-5.5%	-7.1%
Salt River Proj. Ag. I. & P. Dist.	G, C	17,397,426	-12.1%	-13.5%
Houston Lighting & Power Co.	P, C	45,444,647	-0.2%	6.7%
Georgia Power Co.	P, C	62,676,691	-3.5%	3.4%
Texas Utilities Electric Co.	P, C	75,450,682	-5.4%	1.4%

-13.5% (Salt River Proj. Ag. I & P Dist.). We can see that the range of estimates of SE^S is larger than that of SE^A.

Next, negative estimates of scale economies with respect to shadow cost were found for five of the 182 electric utilities. Thus, if we measure economies of scale with respect to shadow cost rather than actual cost, some utilities with scale diseconomies are turned out to operate with scale economies.

The more interesting findings are as follows. When economies of scale are measured with respect to shadow cost, the three utilities which switched from scale diseconomies to scale economies are all the privately-owned utilities, whereas the remaining five utilities with scale diseconomies are all the publicly-owned utilities. This situation can be easily seen in table 5-3. Furthermore, these five utilities are producing the largest output in our publicly-owned utilities sample. Here, it is necessary to remind what we found before--in case of producing more electricity than 725,106 MWH, publicly-owned utilities have higher AC than privately-owned utilities. As a result, we can conclude that publicly-owned electric utilities should produce only a small amount of electricity.

Next, another interesting finding is as follows. The estimates of SE^S are larger than the estimates of SE^A for all the privately-owned utilities in our sample. This result is consistent with the result of Atkinson and Halvorsen (1984), whose sample was confined to only privately-owned utilities. On the other hand, the estimates of SE^S are smaller than the estimates of SE^A for all of the publicly-owned utilities in our sample.

Elasticities of Demand and Substitution

Using eq.(3-40), eq.(3-41) and eq.(3-42), we averaged the own-price elasticities, the cross-price elasticities and the elasticities of substitution over utilities in our sample. The estimated results are presented in table 5-4. The demand for labor is the most responsive to price in case of privately-owned utilities, whereas the demand for fuel is most responsive in case of publicly-owned utilities. This situation might be related with the possible differences in capital structure between publicly-owned and privately-owned utilities.

On the other hand, in case of publicly-owned utilities, the cross-elasticities and the elasticity of substitution between capital and labor have a negative sign, implying the capital-labor complementarity.

Table 5-4
Estimates of Elasticities of Substitution and Price Elasticities

Price Elasticities	Total	Privately-owned	Publicly-owned
E_{KK}	-0.1304	-0.0797	-0.2309
E_{LL}	-0.4016	-0.5013	-0.2039
E_{FF}	-0.1886	-0.1251	-0.3146
E_{KL}	0.0185	0.0311	-0.0066
E_{KF}	0.1119	0.0485	0.2376
E_{LK}	0.1979	0.3681	-0.1396
E_{LF}	0.2038	0.1332	0.3437
E_{FK}	0.1507	0.0837	0.2837
E_{FL}	0.0379	0.4177	0.0309
Elasticities of Substitution			
σ_{KL}	0.2188	0.4853	-0.3099
σ_{KF}	0.2734	0.1380	0.5419
σ_{LF}	0.7125	0.6734	0.7902

CHAPTER 6
CONCLUSIONS

In our theoretical study, we have shown that the relative performance of publicly-owned and privately-owned enterprises will depend on the effectiveness of respective incentive systems, regulatory policy, the degree of competition in the market and the technology in the industry. Next, through the empirical analysis, we tried to evaluate the role and significance of the above various factors.

The estimation results on the relative performance of the different types of ownership indicate that privately-owned electric utilities are more cost efficient than publicly-owned electric utilities at very large output levels and are less efficient at very small output levels. The evidences prior to this study on this issue have been mixed.

On the other hand, contrary to our theoretical expectations, the estimates of parameters reflecting different market structure are insignificant. From these less informative results, we can suppose the following possibilities. First, as our results show, the relative performance in electric generation industry might be mainly affected by the different ownership types rather than the different market structures. Second, since the combined utilities defined as monopoly produce multiple products--electricity and gas, the dummy variable employed for competition and monopoly may be correlated with any economies of scope. Thus, the difference in cost resulted by different market structures may be offset by any economies of scope. If it is true, a more sophisticated approach on the economies of scope is required for future research. Third, like electric industry, when market power is significant, and particularly when utilities' behavior is subject to detailed regulation, we can suppose that there is little empirical justification for a general presumption in favor of either type of market structure.

Taken in conjunction with our empirical results on the U.S. electric generation industry, we are carefully led to the conclusion that, since electric utilities--even privately-owned utilities in competitive environment--are extensively regulated, it is hard to find the conclusive evidence supporting the relative importance of a competitive environment for the success of privatization.

Future work could create variables which would measure load factors and the efficiencies of different fuels in generating electricity. This was, however, beyond the scope of this study.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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